

# Spins in Gluino Decays

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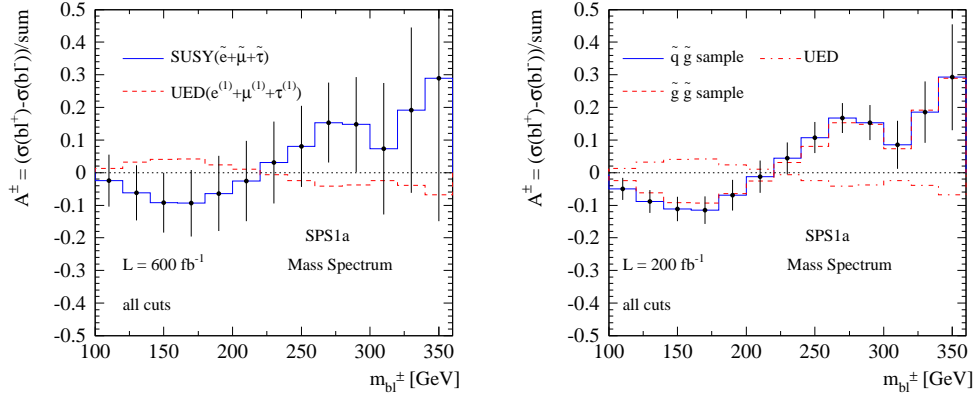
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**Abstract.** To unambiguously claim that we see a gluino at the LHC we need to prove its fermionic nature. Looking only at angular correlations we can distinguish a universal extra dimensional interpretation of a gluino cascade decay (assuming a bosonic heavy gluon) from supersymmetry. In addition to the known lepton–hadron asymmetries we also use of purely hadronic correlations in the gluino–sbottom decay chain.

Looking for charged leptons in gluino decays we can test supersymmetric QCD: like–sign dileptons occur in gluino pair production because the Majorana gluino can decay to  $q\tilde{q}^*$  or  $\tilde{q}\tilde{q}$ , where the (anti)squark decay yields a definite–charge lepton [1]. This recipe for identifying a strongly interacting Majorana fermion (called gluino) has a loop hole. If the particle responsible for a gluino–like cascade decay is a boson [2, 3] with adjoint color charge, like–sign dileptons naturally occur as well. We need to show that the gluino candidate is a fermion [4]. Such a determination of quantum numbers of new particles is a necessary addition to measuring their Lagrangian’s parameters at LHC [5, 6, 7], because these studies implicitly assume that we know the spin of all new particles.

Depending on the mass spectrum, the gluino mass can be determined in the cascade decay  $\tilde{g} \rightarrow b\tilde{b}_1^*/\bar{b}\tilde{b}_1$ , where the light sbottom decays through  $\tilde{b}_1 \rightarrow \tilde{\chi}_2^0 \rightarrow \tilde{\ell} \rightarrow \tilde{\chi}_1^0$  [5, 8]. This well-studied decay we use for our spin analysis.

In the similar case of a squark decay we know how to show that the  $\tilde{q}_L$  is indeed a scalar [9, 10]: first, we assume (for gluino decays to bottoms we know) that all SM particles radiated from the cascade decay are fermions. To determine the spin of the decaying particle all we have to do is compare the SUSY cascade with another interpretation, where the intermediate states have the same spin as their SM partners. Such a model are Universal Extra Dimensions (UED) [2, 3]. There are many ways to discriminate ‘typical’ UED and SUSY models. Direct spin information is generally extracted from angular correlations or Lorentz–invariant normalized invariant masses. For example, if we knew which of the leptons in the squark decay is radiated right after the quark we could use  $m_{q\ell}$  to distinguish UED from SUSY cascades [5, 9, 10]. Instead, the  $\tilde{q}_L$  cascade analysis relies on an asymmetry of squark vs. anti–squark production with a gluino [10]. For our gluino decay tagged bottoms can include a lepton, which allows us to distinguish  $b$  and  $\bar{b}$  on an event–by–event basis.



**FIGURE 1.**  $A^\pm(m_{b\ell})$  for the gluino-pair channel after acceptance cuts and for the gluino-pair and squark-gluino channels after background rejection cuts.

### Lepton–Bottom Correlations

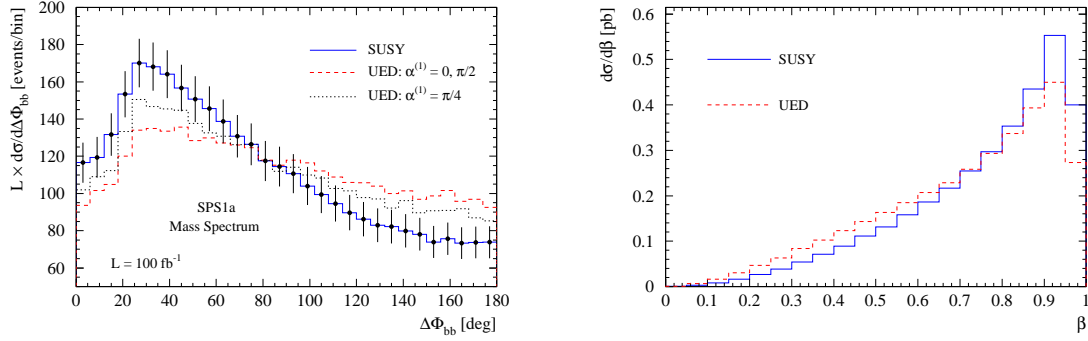
For a quantitative study we choose the parameter point SPS1a [11]. The NLO production rates are 7.96 pb for  $\tilde{g}\tilde{g}$  and 26.6 pb for  $\tilde{q}\tilde{g}$  [12]. To avoid combinatorial backgrounds we require one gluino decay through the short cascade with a light-flavor squark decaying into one light-flavor jets and the LSP. For the second gluino we require two tagged bottom jets in the long cascade through a slepton. This selection means that it is straightforward to also include the large associated  $\tilde{q}\tilde{g}$  production, where the squark decays to a jet and the LSP. The dominant SM background is obviously  $t\bar{t}$ +jets. All backgrounds include uncorrelated leptons from independent decays. An efficient way to eliminate these backgrounds beyond the level  $S/B \sim 1$  is to subtract the measured opposite flavor dileptons from the same flavor dileptons [13]. Because the precise prediction of the remaining tiny backgrounds is beyond the scope of this paper we will not include them in our analysis.

For SPS1a parameters, the mass hierarchy has a favorable impact on the decay jet momenta. Just picking the harder of the two bottom jets we could distinguish between near and far jets. We choose to ignore this spectrum dependent approach in favor of the general method of distinguishing bottom and anti-bottom jets. For the simulation we use UED in Madevent/Smadgraph [14]. Detector effects and tagging efficiencies yield an additional 0.11 dilution factor for the signal [15]. We assume the SPS1a spectrum also for the UED particles and normalize the rates to the SUSY case. All information left in the  $m_{b\ell}$  shape are now angular correlations. We construct the asymmetry

$$A^\pm(m_{b\ell}) = \frac{d\sigma/dm_{b\ell^+} - d\sigma/dm_{b\ell^-}}{d\sigma/dm_{b\ell^+} + d\sigma/dm_{b\ell^-}} \quad (1)$$

In Fig. 1 we show some results after acceptance and background rejection cuts. The asymmetry is not biased by the harder cuts. The  $\tilde{q}\tilde{g}$  and  $\tilde{g}\tilde{g}$  contributions can indeed be added naively.

The details of the gluino decay chain reveal something else [4]: two leptons in the cascade usually come from an intermediate light-flavor slepton. Alternatively, the decay



**FIGURE 2.** Left: Azimuthal angle between the two bottom jets. Right: boost of the gluino and heavy KK gluon.

can proceed through staus. For SPS1a the lighter selectron/smuon is mostly right handed whereas the lighter stau is mostly left handed, due to the renormalization group running and the fairly large  $\tan\beta = 10$ . This means the stau contribution to the mass asymmetry is opposite to the selectron/smuon contribution and that it can wash it out. Luckily, its numerical impact can be suppressed because leptons from tau decays are significantly softer.

### Bottom–Bottom Correlations

The correlation between a lepton and a bottom jet is only one of the distributions we can use. Unfortunately, just as for squark decays purely leptonic distributions are not as useful as mixed lepton–jet correlations [10]. For the gluino decay chain we can build purely hadronic correlations. They have the advantage of being independent of the  $\tilde{\chi}_2^0$  decay, which can be complicated by intermediate gauge bosons or three-body decay kinematics.

In Fig. 2 (left) we present the distribution  $d\sigma/d\Delta\phi_{bb}$ , which exhibits a distinct behavior for SUSY and UED decay chains and can be used to construct an asymmetry:

$$\frac{\sigma(\Delta\Phi_{bb} < 90^\circ) - \sigma(\Delta\Phi_{bb} > 90^\circ)}{\sigma(\Delta\Phi_{bb} < 90^\circ) + \sigma(\Delta\Phi_{bb} > 90^\circ)} \quad (2)$$

It assumes small values  $0.08 \pm 0.02$  for the UED spin assignment. For the SUSY interpretation it is significantly larger  $0.24 \pm 0.02$ . The quoted errors are statistical errors for the combination of the gluino–pair and gluino–squark production channels with an integrated luminosity of  $100 \text{ fb}^{-1}$ . Using the  $\tilde{b}_2$  contribution to the decay chain [4] we can see that the different behavior shown in Fig. 2 is mostly due to the boost of the heavy gluino or KK gluon. This difference we show in Fig. 2 (right).

## Outlook

Proving the presence of a Majorana gluino is the prime task for the LHC to show that new TeV-scale physics is supersymmetric. It has been known for a long time that like-sign dileptons are a clear sign for its Majorana nature [1]. The loop hole in this argument is to show that the gluino candidate is a fermion.

Using a set of lepton-bottom [10] and bottom-bottom asymmetries we distinguish between the SUSY and the UED cascade interpretations and thus determine the spin of the gluino [4]. However, we also find that the spin information in the decay kinematics is always entangled with the left and right handed sfermion couplings [16, 4].

*Acknowledgments:* We would like to thank Martin Schmaltz, Gustavo Burdman, Chris Lester, and Matthew Reece for their insightful comments.

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